# Acoustic Voltmeter

## hear what you measure

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With the test probe secure (you hope) on the resistor leg, turning your head to view the voltmeter indication is not always a good idea. While your eyes focus to see the measured value on the meter scale, the probe may wander off, cause a short circuit and maybe destroy a component or two. No such problems with this month's Mini Project.

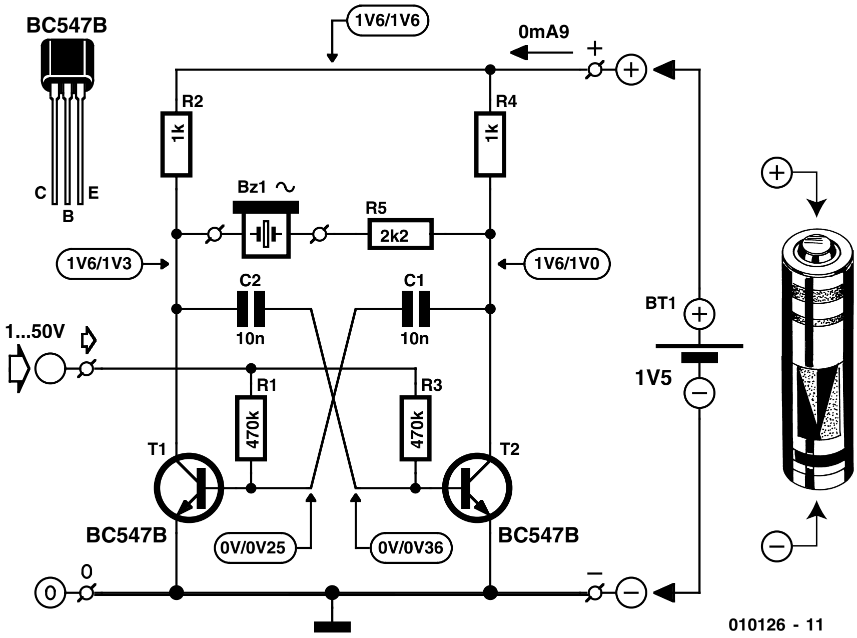


Figure 1. A simple multivibrator supplying its output signal into a passive buzzer.

The little circuit described in this month's instalment of **Mini Projects** effectively converts an electrical voltage into an acoustic (audible) signal. The higher the voltage you measure, the higher the frequency you will hear. Although this type of indication is not as accurate as the trusty voltmeter with a moving-coil meter or a digital readout, the clear advantage is that you can remain concentrated on the measurement location in the circuit without risking as much as glance at the indicating instrument. With some practice, you will soon achieve surprising accuracy using the 'acoustic' method.

## Multivibrator

As you can see from **Figure 1**, the circuit consists of a simple multivibrator in which the base current to both transistors is furnished by the circuit being 'probed into'. A piezo ceramic sounder (a.k.a. 'passive buzzer' or 'ac buzzer') converts the rectangular voltage produced by the Acoustic Voltmeter into an audible signal. At a measured voltage of about 10 V, the frequency produced is about 1 kHz. From about 2 V onwards, a linear relation exists between measured voltage and frequency produced.

The input voltage range of the meter extends to well over 50 V. Negative voltages do not produce a frequency. They do not damage the circuit either, being clamped to a safe level of about –9 V by the internal zener diodes at the base terminal of the transistors. An on/off switch is superfluous as without an input voltage there is no current flow.

Alternating voltages (VAC) may also be measured without problems. These produce a rather special output sound, the frequency produced being modulated by that of the measured alternating voltage. This also enables unsteady direct voltages to be identified spot on, as well as slowly fluctuating or heavily rippled ones.

## Practice!

The Acoustic Voltmeter is quickly and easily built using the spacious circuit board shown in **Figure 2**.

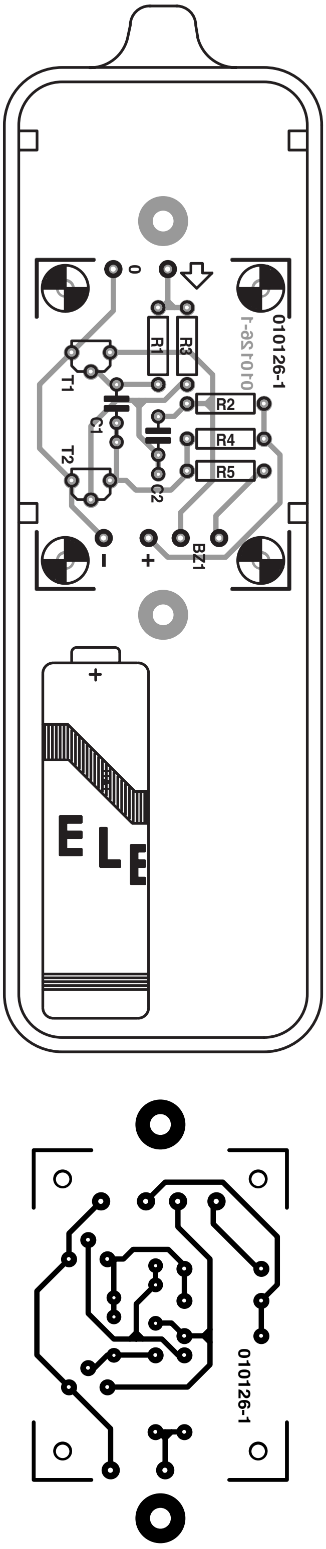
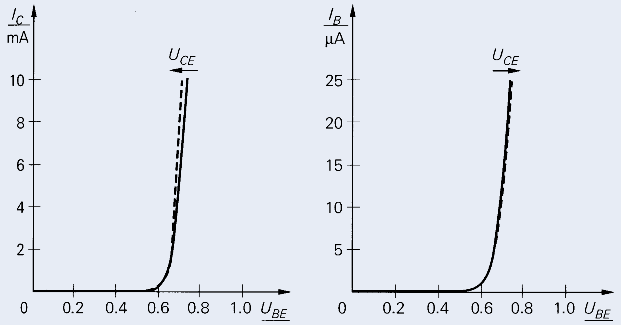


Figure 2. Copper track layout of the PCB designed for the Acoustic Voltmeter (not available ready-made).

## A matter of gain

Theoretically, the voltages at the base and collector terminals of the transistors in this circuit should be identical. Although this is actually the case when the circuit is not active (first values), different values are found once everything starts working (second value). An explanation for this apparent oddity is given below.
A small-signal transistor like the BC547 is characterised by its current gain, $H_{FE}$, which expresses the ratio of collector current $I_c$ to base current $I_b$, as in

$$H_{FE} = I_c / I_b$$



**a** transfer characteristic **b** input characteristic

This factor is a measure of the transistor's typical static current gain. By contrast, the dynamic current gain (a measure of the current change ratio), is expressed as ß or $h_{FE}$. In the case of most small-signal transistors like the BC547, $H_{FE}$ equals $h_{FE}$ for all practical purposes.
Unfortunately it is not possible for semiconductor manufacturers to produce transistors to exact gain specifications. For example, the datasheet of the BC547 loosely indicates a gain of '110-800' at a constant collector current. Fortunately, this rather unwieldy range is divided into three sub-classes of gain, each identified by the suffix in the transistor type number. When using a BC547A, designers should expect a gain of 110-220, while a BC547B and a BC547C are marked by gain ranges of 220-450 and 420-800 respectively. Even when using two B547B's in this circuit, grave differences may occur as a result of the exact gain figure of each transistor. In spite of this, the differences are tolerable even if they result in… different measured values!

Apart from the transistors and the battery, there are no polarized components. The buzzer, too, may be fitted either way around. The completed circuit may be built into a largish probe-style case. The PCB is secured in the case using a glue gun or double-sided tape. The probe tip may be connected to the circuit input via a short piece of wire.

The buzzer is not exactly loud, being operated at just 1.5 volts. If necessary, a few small holes should be drilled in the probe case where the buzzer is secured to the inside.

You'll soon find that the actual use of our little instrument requires some getting used to. Many comparative measurements will be required against the values indicated by an ordinary voltmeter. After some time, you should be able to achieve 'acoustic resolution' of about one volt. Alternating voltages require further practicing before you are ale to tell their approximate level and frequency. Master Class users will also be able to recognize the waveform!

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### COMPONENTS LIST

**Resistors:**
R1,R3 = 470kΩ
R2,R4 = 1kΩ
R5 = 2kΩ2

**Capacitors:**
C1,C2 = 10nF

**Semiconductors:**
T1,T2 = BC547B

**Miscellaneous:**
BZ1 = passive (AC) buzzer
Bt1 = AA (R6/UM3) battery with holder
Probe case with probe tip